HYCOM Consortium for Data Assimilative Modeling

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LONG-TERM GOALS

The goal of the project is to make HYCOM (HYbrid Coordinate Ocean Model) a state of the art community ocean model with data assimilation capability of sea surface height from altimetry, sea surface temperature from MCSST and in-situ data. The ultimate goal is to have an eddy-resolving assimilative fully global nowcast/forecast system running in real time that will provide boundary conditions to a variety of higher resolution coastal models.

OBJECTIVES

This is a collaborative 5 year (FY00-04) National Ocean Partnership Program (NOPP) project between several research groups with Eric Chassignet as the overall lead project PI. The goal is to develop and evaluate HYCOM, a scalable and data assimilative generalized (hybrid) coordinate ocean model. The focus will be on an eddy resolving Atlantic domain (with 7 km resolution at mid latitudes) and a coarser resolution global domain.

APPROACH

Many aspects of ocean modeling are included in this project. The modeling components are described in details in other HYCOM related ONR reports. This report will focus on some of the assimilation components of the project.

The approach is to implement several different assimilation techniques starting with simple incremental updating. More sophisticated algorithms such as a multivariate optimal interpolation (MVOI) analysis, the parameter matrix objective analysis (PMOA, Mariano and Brown, 1992), the singular evolutive extended Kalman filter (SEEK, Pham et al., 1998), the Markov random field information filter (MRFIF, Chin et al.1999) and the ensemble Kalman filter (Evensen, 1994) will also be implemented by the HYCOM/NOPP consortium. The assimilation techniques will be evaluated as a function of computational efficiency and prediction accuracy. The computational requirements will be

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an important part of the comparison. A real time system will have a limited amount of computer time available and the model with the data assimilation will have to run within this time limit. The validation of the results from the assimilation experiments is an important part of the project. Data not being assimilated will be used to validate the model solution.

WORK COMPLETED

A meeting of the HYCOM/NOPP partnership was held in February 2004 to review progress and update plans and milestones, technical issues and responsibilities of the participants.

The work on improving the baseline assimilation system in HYCOM has continued. In December of 2003 a meeting took place in Miami where the plans for the implementation of the next generation assimilation technique for the near real time system were discussed. It was decided that the NRL Coupled Ocean Data Assimilation (NCODA), developed by Dr. Cummings would be the next technique to be implemented. The method used in NCODA is an oceanographic version of the multivariate optimum interpolation (MVOI) technique widely used in operational atmospheric forecasting systems. A description of the MVOI technique can be found in Daley, (1991). The implementation of this technique has continued under the NOPP project "U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)" and additional information about the implementation can be found in the report from this project.

The 1/12° version of the Atlantic HYCOM has continued to run in near real time. The operational MODAS analysis of available satellite altimeter anomalies is assimilated into the model. The mean SSH from the 1/12° MICOM experiment with ECMWF atmospheric forcing is currently being used with the anomalies from the MODAS analysis. A vertical projection of the surface observations using the Cooper and Haines technique, (Cooper and Haines, 1996) is a part of the assimilation. This year a relaxation to the MODAS SST analysis has been added to the system. The system runs every Wednesday and consists of a 10 day hindcast and a 14 day forecast. The results are displayed on the HYCOM Consortium web page at http://hycom.rsmas.miami.edu. It includes comparisons to unassimilated observations, e.g. the independent frontal analysis of high resolution MCSST data performed by NAVOCEANO. The web page that is available to the project participants is also being updated on a weekly basis. This site is used in the evaluation of the model performance and to see the effect of future upgrades to the model and the assimilation scheme. Data from the system are now available in near real time. The HYCOM Consortium web page has a link to a data server where the model fields are available for downloading in a variety of formats (e.g. netCDF, binary), http://hycom.rsmas.miami.edu/dataserver. ARGO data from the GODAE server has been used in the model/data comparison of the near real-time system. The profiles from this data set usually contain both a temperature and a salinity profile. The ARGO data set will be an important data source for the MVOI assimilation scheme mentioned above. In addition, the model has been compared to observations of currents across several sections in the equatorial Atlantic. The mean over a one year time period was used in these comparisons.

The comparison of several different mean SSH fields from both numerical models and observational data sets is now near completion. A paper reporting on the results of this study is in the final stages of preparation. In addition to the comparison with in situ data consisting of concurrent and collinear measurements of sea surface heights from the TOPEX satellite and dynamic heights computed from data obtained from bathythermographic surveys performed by the Naval Oceanographic Office, the frontal location of the Gulf Stream was compared to an independent set of frontal analysis of MCSST

data. The strength of the currents across different sections was also compared. This included the Yucatan Channel, the Florida Current and the Gulf Stream.

RESULTS

The near real-time 1/12° Atlantic model has been running since the fall of 2002. The system is forced by the Fleet Numerical Meteorology and Oceanography Center (FNMOC) Navy Operational Global Atmospheric Prediction System (NOGAPS). The current assimilation system is computationally very efficient. It increases the run time of the model by only a few percent compared to the model run without assimilation.

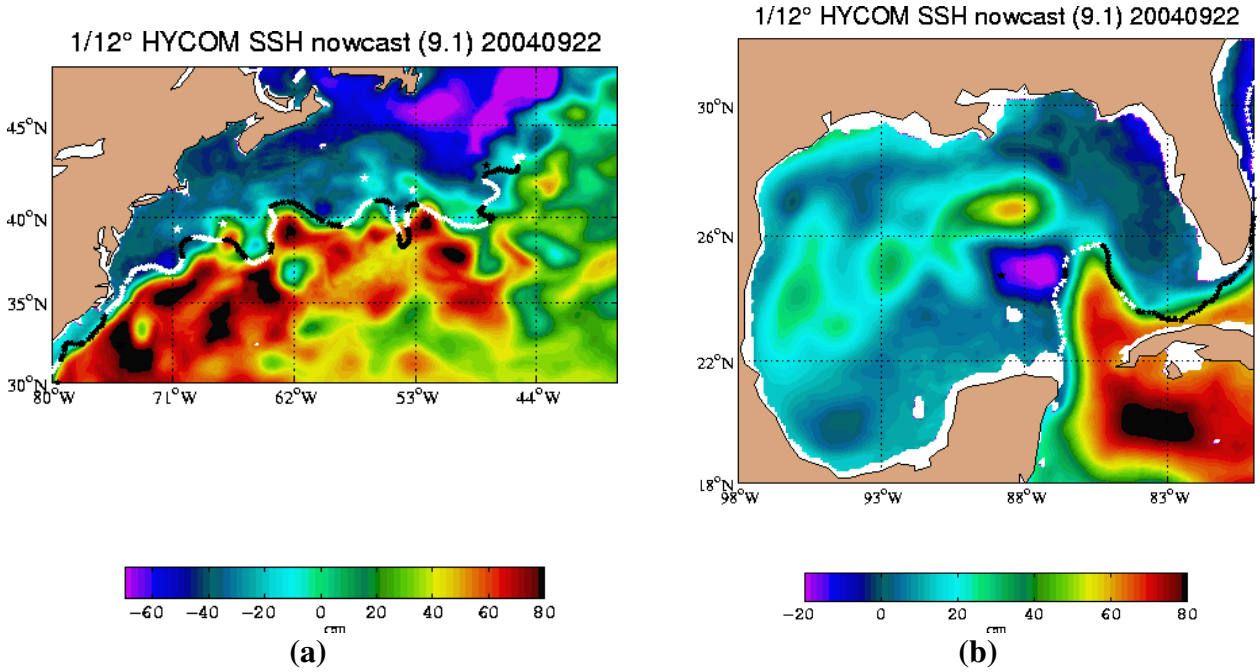
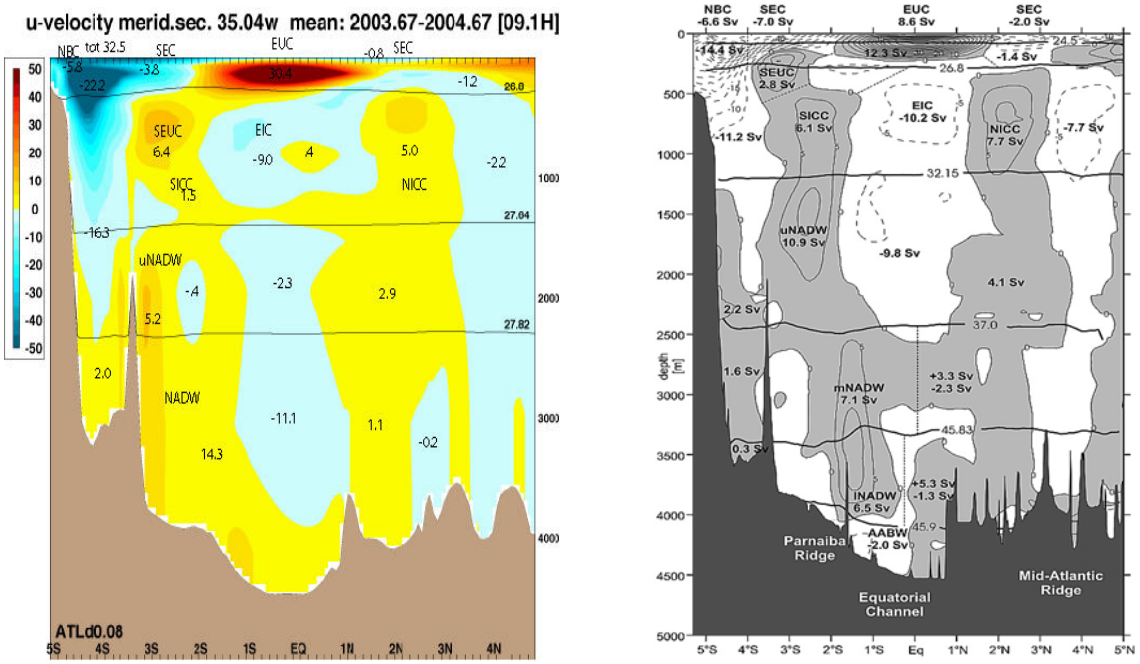


FIGURE 1. (a) The sea surface height from the 1/12° Atlantic HYCOM in the Gulf Stream region on 22 September 2004 (b) The sea surface height from the 1/12° Atlantic HYCOM in the Gulf of Mexico region on 22 September 2004. Overlain is an independent frontal analysis of high resolution MCSST observations performed at NAVOCEANO. The frontal position is marked in black if the observations are more than 4 days old. There is a very good agreement between the models frontal location and the one determined from the MCSST frontal analysis.

Examples of the results from the 1/12° Atlantic model can be seen in figure 1a and b. The figures show the model SSH for the Gulf Stream region on 22 September 2004, figure 1a, and the Gulf of Mexico region, figure 1b. Overlain on the SSH is an independent frontal analysis of MCSST data performed at NAVOCEANO. The agreement between the model and the independent observations is very good.



(a) **(b)**

FIGURE 2. (a) A vertical section of the mean velocity across 35°W from 5°S to 5°N from the 1/12° Atlantic system. The mean is over the time period July 2003 through August 2004. (b) Observations of transports across 35°W (from Schott et al., 2003)

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Figure 2 shows an example of the comparison between the prediction system and a set of independent observations. The mean velocity/transport across 35°W between 5°S and 5°N from the model is shown in figure 2a, while a corresponding plot of observations from Schott et al. (2003) is shown in figure 2b. There is a good agreement between the model and the observations both when it comes to structure and amplitude.

The NOPP project "U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)" that started this year, is designed to take HYCOM from the research and development performed under this NOPP project to the development of operational eddy resolving global and basin scale ocean prediction systems for the U.S. Navy and NOAA.

IMPACT/APPLICATIONS

The intended impact of the HYCOM/NOPP project is the development of a next generation hybrid coordinate ocean model which will have a greater range of applicability than traditional single coordinate ocean models. The vertical coordinate in HYCOM is designed to make optimal use of three types of vertical coordinates, isopycnal, σ and z-level, although it is not limited to these types. The project has implemented the first near real-time 1/12° HYCOM Atlantic nowcast/forecast system with a public web page showing the results from the system. The new NOPP/GODAE/HYCOM project will work toward an eddy-resolving global ocean prediction system with 1/12° (~7 km mid-latitude) resolution running by the end of FY06 and 1/25° (3-4 km mid-latitude) resolution by the beginning of the next decade including an embedded ice model and the capability to host nested littoral models with even higher resolution. The HYCOM consortium is participating in the Global Ocean Data

Assimilation Experiment (GODAE) (2000-2007) and is contributing to the GODAE goal of helping to justify a permanent global ocean observing system by demonstrating real-time global ocean products with a customer base. The global fully eddy-resolving version of HYCOM is planned for transition to NAVOCEANO as a replacement for their current operational ocean model.

TRANSITIONS

None

RELATED PROJECTS

The results described here are a part of a HYCOM/NOPP project with participation from several different research groups. The groups include E.P. Chassignet (Coordinator), A. Mariano and G. Halliwell (University of Miami), T.M. Chin (JPL/University of Miami), R. Bleck (LANL), H. Hurlburt, P. Hogan, R. Rhodes, C. Barron, A. Wallcraft and G. Jacobs (Naval Research Laboratory), O.M. Smedstad and B. Lunde (Planning Systems Inc.), W.C. Thacker (NOAA/AOML). The NOPP project "U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)" will develop a global 1/12° version of HYCOM which is planned for transition to the Naval Oceanographic Office in 2007.

REFERENCES

Fox, D.N, W.J. Teague, C.N. Barron, M.R. Carnes and C.M. Lee, 2002: The Modular Ocean Data Assimilation System, Journal of Atmospheric and Oceanic Technology. 19, 240-252.

Chin, T.M., A.J. Mariano and E.P. Chassignet, 1999: Spatial regression with Markov Random Fields for Kalman filter approximation in least-squares solution of oceanic data assimilation problems. Journal of Geophysical Research, 104, 7991-8014.

Cooper, M. and K. Haines, 1996: Altimetric assimilation with water property conservation. Journal of Geophysical Research, 101, 1059-1077.

Daley, R., 1991: Atmospheric Data Analysis. Cambridge University Press, Cambridge, 457 pp.

Evensen, G. 1994: Sequential data assimilation with a nonlinear quasi-geostrophic model using Monte Carlo methods to forecast error statistics. Journal of Geophysical Research, 99, 10143-10162.

Hurlburt, H. E., D. N. Fox and E. J. Metzger, 1990: Statistical inference of weakly-correlated subthermocline fields from satellite altimeter data. Journal of Geophysical Research, 95, 11375-11409.

Mariano, A.J. and O.B. Brown, 1992: Efficient objective analysis of dynamically heterogeneous and nonstationary fields via the parameter matrix. Deep-Sea Research, 39 (7/8), 1255-1271.

Pham, D.T., J. Verron and M.C. Roubaud, 1998: A singular extended filter for data assimilation in oceanography. Journal of Marine Systems, 16, 323-340.

Schott F. A., M. Dengler, P. Brandt, K. Affler, J. Fischer, B. Bourles, Y. Gouriou, R. L. Molinari, and M. Rhein, 2003: The zonal currents and transports at 35°W in the tropical Atlantic, Geophysical Research Lett., 30 (7), 1349, doi:10.1029/2002GL016849.

PUBLICATIONS

Metzger, E.J., P.J. Hogan, O.M. Smedstad, E.P. Chassignet, H.E. Hurlburt, A.J. Wallcraft and T.L. Townsend, 2003: Basin-scale Ocean Prediction with the HYbrid Coordinate Ocean Model, 2003 DoD HPC Users Group Conference Proceedings, Bellevue, WA, 9-13 June 2003, 299-305.

Chassignet, E. P., H. E. Hurlburt, O. M. Smedstad, C. N. Barron, D. S. Ko, R. C. Rhodes, J. F. Shriver, A. J. Wallcraft, and R. A. Arnone, 2004: Assessment of Ocean Prediction Systems in the Gulf of Mexico using Ocean Color. Submitted to AGU Monograph Series.